Transport Canada Transports Canada

TP 13795 E

National Civil Aviation Safety Committee

Sub-Committee on Runway Incursions

Final Report

September 14, 2000

Canada

Table of Contents

1. Introduction ____ *1*

2. Methodology ____ *2*

2.1 General ____ 2

2.2 Runway Incursion definition ____ 2

2.3 Runway Incursion Severity Definition ____ 3

2.4 Source and Scope of Occurrence Information ____ 4

2.5 Validation and Analysis of Occurrence Data ____ 4

3. Analysis ____ *6*

3.1 Trend Analysis ____ 6

3.2 Contributing Factors ____ 7

3.2.1 Traffic Volume ____ 7

3.2.2 Capacity-Enhancing Procedures ____ 10

3.2.3 Airport Layout(s) ____ 13

3.2.4 Complexity ____ 16

3.3 Human Performance Analysis ____ 17

3.3.1 CADORS Database ____ 17

3.3.2 Transportation Safety Board Reports ____ 18

3.3.3 NAV CANADA Fact-Finding Boards ____ 18

3.3.4 Human Performance Discussion ____ 19

3.3.5 Limitations of the Data ____ 19

3.3.6 Training and Awareness ____ 20

3.4 Site Analysis ____ 22

3.4.1 Calgary International Airport ____ 23

3.4.2 Boundary Bay Airport ____ 27

3.4.3 Edmonton City Centre Airport ____ 28

3.5 Process Analysis ____ 28

3.5.1 Reactive Mechanisms ____ 28

3.5.2 Proactive Mechanisms ____ 29

4. Recommendations ____ *31*

Annex A – Weighted Aggregate Risk Tables ____ *A-1*

Annex B – Boundary Bay Action Planning ____ *B-1*

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1. Introduction

In 1999, Transport Canada (TC) noted an increase in aviation safety occurrences involving runway incursions at Canadian airports. The issue was raised at the National Civil Aviation Safety Committee (NCASC) meeting on July 13, 1999, where it was agreed that a sub-committee be formed to develop a national strategy to specifically address the runway incursion issue.

The sub-committee on runway incursions (SCRI) was chaired by the Risk Assessment and Safety Studies Branch of Transport Canada, Safety Programs, Strategies and Coordination, and included members from the following organizations:

- TC Aerodrome Safety ;
- TC Air Navigation Services and Airspace;
- TC Commercial and Business Aviation;
- TC Aviation Enforcement;
- TC Safety Services;
- TC General Aviation; and
- NAV CANADA.

An interim report on the activities of the sub-committee was presented to the NCASC on 14 March 2000 and was subsequently presented at the Civil Aviation Safety Symposium (CASS) in St. John's NFLD on 8 May 2000. This document represents the final report of the SCRI to the NCASC.

Canada

2. Methodology

2.1 General

To gather information about runway incursions, the sub-committee participated in runway incursion meetings, organized by NAV CANADA, at Ottawa, Calgary, Vancouver, Abbotsford, Nanaimo and Medicine Hat. Pilots and representatives from local flying schools, commercial aviation companies, airport authorities, Transport Canada, Transportation Safety Board and NAV CANADA regional offices were invited to attend the "stakeholder meetings". These forums were well attended and provided an excellent source of information about local issues of relevance to runway incursions.

Runway incursion occurrence information, dating from 1993 to present, was extracted from various data sources and was used by the SCRI to develop trend information and other statistics.

A comprehensive literature search was conducted to identify the activities and findings of other groups and agencies similarly engaged in the analysis of runway incursions. The SCRI took particular care to remain cognizant of the undertakings of the International Civil Aviation Organization (ICAO) and the United States (US) Federal Aviation Administration (FAA), Runway Incursion Action Team (RIAT).

An "expert-panel" on runway incursions, comprising representatives from government and industry, was organized by NAV CANADA. The expert-panel used the information that had been gathered to identify preventive strategies that could be implemented by NAV CANADA, independently, or in partnership with government and industry. The SCRI participated in the "expert-panel" meetings, which occurred in Winnipeg during the period 26-30 June 2000. The expert panel's findings and recommendations are referenced in this document but will be promulgated in full and under separate cover by NAV CANADA.

2.2 Runway Incursion definition

The US FAA defines a runway incursion as:

"Any occurrence at an airport (with an operating control tower) involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in a loss of separation with an aircraft taking off, intending to take off, landing, or intending to land."

Although Transport Canada has not promulgated a formal definition for runway incursion, the SCRI decided not to adopt the FAA definition for runway incursion. Working in collaboration with NAV CANADA, the SCRI developed a working definition for runway incursions that emphasizes risk, rather than outcome, and which can be readily applied to events at both controlled and uncontrolled airports. The following definition was adopted by the SCRI and was used to classify occurrence reports:

"The unauthorized or unplanned presence of a vehicle, person or an aircraft on or near any serviceable runway[1]."

In order to capture incursion events on landing surfaces other than runways and to remove the ambiguity associated with the word "near", the expert panel proposed the following amendment to the SCRI definition:

"Any occurrence at an airport involving the unauthorized or unplanned presence of an aircraft, vehicle or person on the protected area of a surface designated for aircraft landings or departures."

The SCRI recommends that Transport Canada endorse and promulgate this latter version as the "official" Canadian definition for runway incursion.

2.3 Runway Incursion Severity Definition

Various defence strategies exist to help prevent a runway incursion. Examples of these defences include ATS clearance and readback protocols to taxi and/or enter an active runway, airport signs and lights, obligations by ATS personal and aircrew to visually scan a runway before entering and direct intervention by ATS personnel, aircrew or vehicle operators to avert an impending collision. A runway incursion occurs when one or more of these defences is breached. The severity of a runway incursion depends on the circumstances surrounding the event and may be related to the number of defences that failed in allowing the runway incursion.

Severity and frequency are the two components necessary to calculate risk. Whereas the frequency of occurrence can be derived directly from the occurrence data, the severity of each occurrence must be inferred by assessing the circumstances surrounding the event. To assist with this process, the SCRI developed five categories, organized to represent the failure of various levels of defence, for describing the severity of a runway incursion. The severity categories are:

[1] A serviceable runway is any runway that is not closed.

1. **Negligible** - the occurrence would not have caused a collision with an aircraft or vehicle. No intervention required to keep the runway clear. *(Example: An aircraft or vehicle was near (within 200 feet) but not on a serviceable runway and stopped short of the runway surface without intervention).*

2. **Low** - the occurrence was unlikely to result in a collision with an aircraft or vehicle. ATS or pilot intervention was required to keep the runway clear. *(Example: A vehicle or aircraft was near (within 200 feet) but not on a serviceable runway and stopped short of the runway surface when contacted by ATC).*

3. **Medium** - the occurrence could have resulted in a collision with an aircraft or vehicle. A vehicle or aircraft was on a serviceable runway without authorization or was cleared onto (or across) a serviceable runway in error. *(Example: An aircraft crosses a serviceable runway without clearance).*

4. **High** - the occurrence could have resulted in a collision with an aircraft or vehicle. A vehicle or aircraft was on a serviceable runway without authorization or cleared in error and a **clear risk of collision** existed. Normally requires ATS intervention to correct. *(Example: Two aircraft take off from the same runway at the same time).*

5. **Extreme** - the occurrence would have resulted in a collision with vehicles and/or aircraft and was prevented only by **last minute evasive action** by the aircrew and/or vehicle operator(s). *(Example: A pilot rejects a take-off to avoid a collision with a vehicle or another aircraft).*

2.4 *Source and Scope of Occurrence Information*

The SCRI retrieved runway incursion occurrence information from the Transport Canada Civil Aviation Occurrence Reporting System (CADORS) database and the NAV CANADA Aviation Occurrence Reporting (AOR) database. Supplemental information on many of these occurrences was derived from NAV CANADA Fact Finding Boards (FFBs) and information contained in the Transportation Safety Board Aviation Safety Information System (ASIS). Runway incursion counts were available in CADORS from 1993 to the present although a laborious manual search was necessary to extract even this basic information. More detailed runway incursion information was available in the AOR database from December 1997 to present.

2.5 *Validation and Analysis of Occurrence Data*

Occurrence information from the various data sources was validated by the SCRI and subsequently entered into a dedicated runway incursion database. The SCRI found that recent occurrence data were valid and reliable but older

data, particularly those collected prior to 1997, were not sufficiently detailed or accurate to facilitate further analysis. It was therefore decided to concentrate on the occurrence data collected since 1997. Earlier numbers are reported but no detailed analyses of these data were conducted by the SCRI . A severity score was assigned to every valid occurrence reported since 1997.

A risk-analysis methodology was developed to express occurrence frequency, severity and trend information for a given aerodrome as a single value, denoting *weighted aggregate risk*. For each aerodrome of interest, the aggregate risk accruing from vehicle and aircraft runway incursion events was calculated separately for 1997, 1998, 1999 and the first five months of the year 2000. The aggregate risk figure(s) represent the product of average occurrence severity and the number (frequency) of occurrences, as follows:

Aggregate risk (R_A) = average severity *X* number of occurrences

For each aerodrome of interest, a *weighted aggregate risk* (R_A) was then calculated as follows:

$$R_A = 0.5(R_{A(97)}) + 0.75(R_{A(98)}) + 1.0(R_{A(99)}) + 2.0(R_{A(00)})$$

As can be seen, the weighted aggregate risk figure is most significantly influenced by recent occurrences. As well, because the risk value for the year 2000, ($R_{A(00)}$), is derived from occurrences recorded during the first 5 months of the year 2000, the doubling factor applied to this value represents a *conservative* estimate of the aggregate risk for the entire year.

A revised calculation of weighted aggregate risk, using occurrence information from only 1999 and 2000, was completed to make the result more sensitive to recent events, where:

$$r_A = 1.0(R_{A(99)}) + 2.0(R_{A(00)})$$

This value was then used to calculate, for each aerodrome of interest, the weighted aggregate risk per 100,000 movements (r_{AM}) using the annual movement statistics for 1999. A summary of all calculations is provided in Annex A.

3. Analysis

3.1 Trend Analysis

In 1996, 107 runway incursions were reported at Canadian aerodromes. In 1997, 1998 and 1999, the number of runway incursions reported at Canadian aerodromes was 122, 164 and 262 respectively. From 1996 to 1999 the number of runway incursions reported at Canadian aerodromes increased by 145%. First quarter results for the year 2000 comprise 71 runway incursions, representing a 39% increase over the first quarter results for 1999. If this rate persists, it is estimated *conservatively* that total runway incursions for the current year may exceed 300. These figures clearly indicate that the number of runway incursions at Canadian aerodromes have increased sharply in recent years and are continuing to do so.

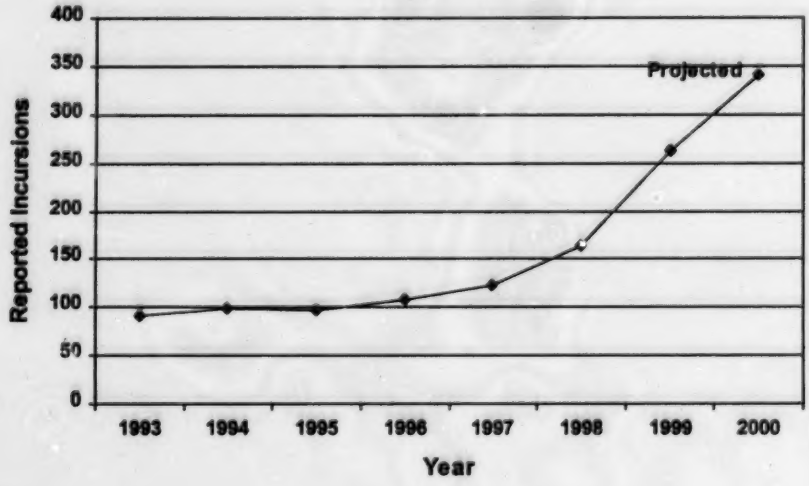

Figure 1 - Runway Incursion Trend

The SCRI examined the runway incursion data for evidence that increased emphasis on runway incursions has led to more diligent reporting, thus causing an *apparent* trend toward higher numbers when no such trend actually exists. Aerodromes displaying a particularly sharp rise or fall in the frequency of runway incursion reports were examined in detail. In all cases, legitimate factors were identified to justify the pronounced changes that were observed in the data. In two cases, the SCRI identified practices and attitudes conducive to the under-reporting of runway incursion events. Finally, and notwithstanding different definitions, the increasing trend in

Canadian runway incursion data is remarkably similar to the trend observed at American aerodromes during the same period of time. For these reasons, the SCRI concluded that the trend information derived from the Canadian runway incursion data is *valid and increasing*.

3.2 Contributing Factors

Having confirmed that the frequency of runway incursions has increased *significantly* during the last 4 years, the SCRI began a lengthy process of consultation and research to identify factors that are potentially responsible for the upward trend. A list of factors was compiled and found to be consistent with the findings of various other studies and investigations into runway incursions. However, the SCRI was unable to identify a single factor, or combination of factors, that have changed so radically as to account for a 145% increase in runway incursions since 1996. Conversely, at many locations where the frequency of runway incursions has generated local concern, the airport authority was found to have taken reasonable steps to correct known deficiencies, typically associated with signs, markings and vehicle control. In light of these findings, the SCRI concluded that a powerful and hitherto unidentified factor was primarily responsible for the increasing trend in runway incursions at Canadian aerodromes.

3.2.1 Traffic Volume

From 1990 to 1995, Canadian air traffic volume[2], measured in movements declined steadily. However, from 1996 to 1999, the *average* traffic volume at Canadian aerodromes has increased by approximately 9.3 percent. At specific airports and *during peak periods*, much higher rates of growth have been recorded over the same period of time. At Calgary International Airport, for example, traffic volume from 1996 to 1999 has increased by 12.3 percent. During the same period, traffic at Boundary Bay airport has increased by 18.4 percent. But what is the relationship between traffic volume and the potential for a runway incursion?

[2] Based on aircraft movement information provided by Statistics Canada.

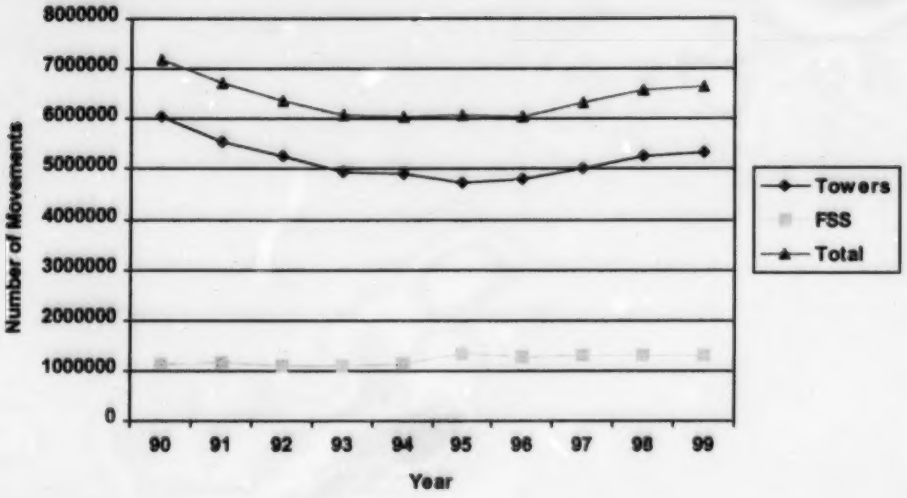

Figure 2 - Aircraft Movements in Canada

Using a single runway model, the number of runway incursion scenarios can be calculated for a given number of aircraft on the manoeuvring surface, as follows:

Number of Aircraft	Number of Incursion Scenarios
1	0
2	1
3	4
4	10
5	24

Table 1 - Runway Incursion Potential, single runway operation.

Referring to table 1, it becomes immediately apparent that the potential for a runway incursion increases more rapidly than traffic volume. For example, a 20% increase in volume (4 aircraft to 5 aircraft), which is typical of the traffic volume increase since 1996 at some Canadian aerodromes, represents a 140% increase in runway incursion potential. It is similarly apparent that smaller average rates of growth, such as those recently witnessed in Canada and forecast for the future, will result in a disproportionately large increase in runway incursion *potential*. In keeping with the laws of probability, and in the absence of significantly improved safeguards, an increase in the *potential* for runway incursions can be expected to be associated with an increase in

actual runway incursion events. This expectation is consistent with the runway incursion trend observed in Canada since 1996[3].

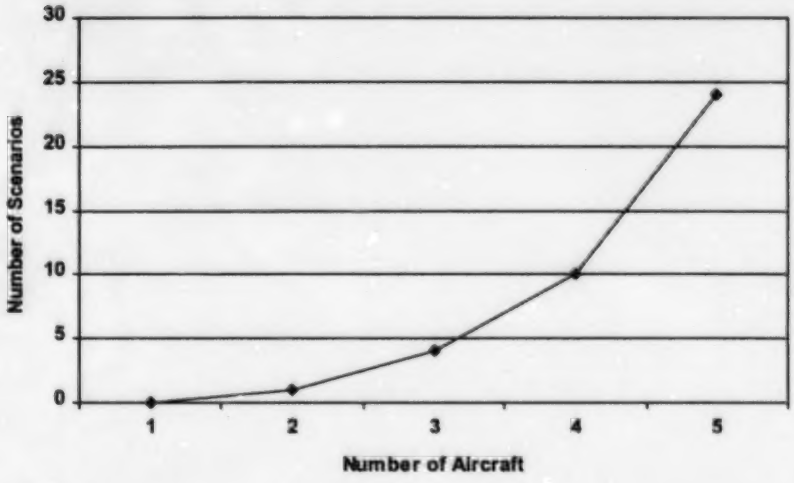

Figure 3 - Runway Incursion Potential: One Active Runway

Empirical evidence of the relationship between traffic volume and runway incursions is also available in the United States, where runway incursion statistics have been maintained since 1988. The following observation was recently made by aviation analyst Lincoln Lounsbury[4]: *"From 1988 to 1990, traffic volume at towered airports in the United States increased 4.76 percent, but the runway incursion rate at these airports increased more than 43 percent. From 1990 to 1993, traffic volume decreased 5.34 percent, and the runway incursion rate quickly dropped by 30 percent. Then, reversing the trend once again, from 1993 to 1998, traffic volume grew only 2.41 percent, but the runway incursion rate climbed an incredible 67 percent."*

[3] From 1993 to 1995 the Canadian air traffic volume was essentially constant and the runway incursion rate during the same period grew by only 5 percent.
[4] Air Line Pilot Magazine, May 1999.

Canada

3.2.2 Capacity-Enhancing Procedures

As volume has increased at major airports, new procedures have been introduced to increase airport capacity. Parallel runway operations, simultaneous intersecting runway operations (SIRO) and intersection departures are examples of procedures that are used to expedite aircraft arrivals and departures. The effect of these *capacity-enhancing* procedures on runway incursion potential can be demonstrated mathematically as shown below. Table 2 depicts the number of incursion scenarios that exist when two parallel runways are in use or when a 2-runway SIRO operation is in effect.

# of Aircraft	1 Runway	2 Parallel Runways	SIRO - 2 Runways
1	0	0	0
2	1	2	3
3	4	8	14
4	10	20	30
5	24	48	72

Table 2 - Runway Incursion Potential, Multiple Runway Operation.

A graph of these results (figure 4) illustrates how these capacity-enhancing procedures, by virtue of their complexity, offer more ways in which a conflict can develop between two or more aircraft. It can also be shown, although not done here, that intersection departures and/or a three runway SIRO operation will further increase the complexity of an airfield operation and create additional opportunities for the manifestation of a runway incursion event.

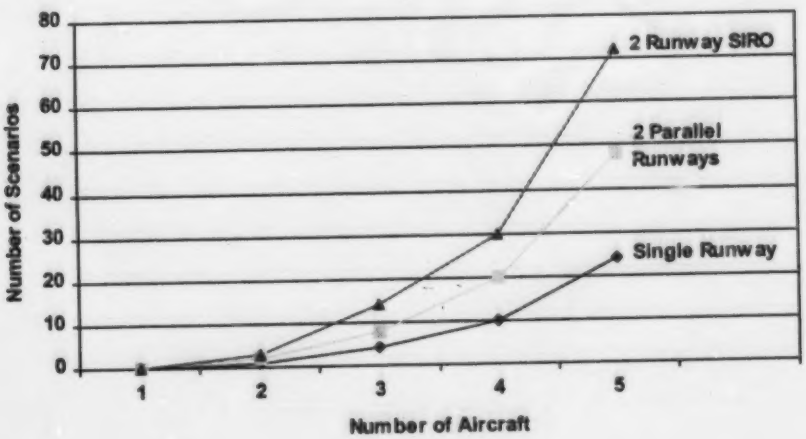

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Figure 4 - Runway Incursion Potential: 2 Active Runways

Two conclusions can be drawn from this basic model. Specifically:

a) As traffic volume increases, runway incursion potential increases more rapidly when capacity-enhancing procedures, such as SIRO and intersection departures, are in effect than when they are not in effect; and

b) If traffic volume remains unchanged, the *potential* for runway incursions will increase when capacity-enhancing procedures are implemented.

In Canada, intersection departures and SIRO are commonly invoked as capacity-enhancing procedures. Guidelines for the conduct of SIRO operations were established in 1991 and SIRO procedures are currently authorized at 18 Canadian aerodromes. However, Canadian Air Regulations and Standards do not place limits on the number of runways that may be simultaneously activated at an aerodrome, even during SIRO operations. To date, very few runway incursions have been linked to capacity-enhancing procedures, although a comprehensive study of the relationship between these procedures and runway incursions has not been undertaken. More significantly, the impact of capacity-enhancing procedures on aerodrome complexity and, by extension, on the cognitive workload experienced by aircrew and ATS personnel operating in this environment, has not been studied in detail. There are currently no standard procedures for measuring the complexity of an aerodrome environment and there is no quantitative data detailing the relationship between aerodrome complexity and human performance. Perhaps for these reasons, no formal or informal guidelines exist to limit the growing complexity of aerodrome environments.

3.2.2.1 *FAA, ICAO and NTSB Recommendations*

In the United States, a 1994 study by the Federal Aviation Administration[5] concluded that certain capacity-enhancing measures have the potential to induce human errors. Significant risk factors were attributed to runway intersection takeoffs, position and hold clearances and SIRO procedures. To mitigate these risks, the FAA study proposed changes to ATC and aircrew procedures to include:

- mandatory readback of taxi route clearances;
- increased emphasis on ICAO standard phraseology;
- use of aircraft exterior lighting to enhance aircraft conspicuity;

[5] Report by airline pilots on airport surface operations: Identified problems and proposed solutions for operational procedures and factors affecting pilot performance.

- ramp-to-ramp crew briefings; and
- the dissemination of information to aircrew about human performance vulnerability to error due to workload, and potential distractions associated with the performance of flight deck tasks.

To date, these recommendations have not been implemented in the United States or in Canada. A recent ICAO document[6] observed that there is *"no evidence of significant progress in implementation of the solutions proposed by the [FAA] study"*. In light of this, the ICAO Air Navigation Commission is currently considering a proposal to introduce these preventive strategies through an amendment to the ICAO Procedures for Air Navigation Services - Aircraft Operations (PAN-OPS). In a related move, the National Transportation Safety Board (NTSB) has recommended[7] that the FAA implement the following procedural changes to reduce the runway incursion potential at American airports:

- require that all runway crossings be authorized only by specific air traffic control clearance, and ensure that pilots receive adequate notification of the change;
- discontinue the practice of allowing departing aircraft to "line up and wait" on active runways at night or in poor weather;
- require that American ATC personnel adhere to the ICAO standard phraseology for airport surface operations, and periodically emphasize to controllers the need to use this phraseology and to speak at reasonable rates when communicating with all flight crews, especially those whose primary language is not English.

In view of the many similarities between American and Canadian aerodrome environments, the pilots who routinely fly in both countries and the obvious advantages of maintaining common standards and procedures, the SCRI believes that Transport Canada should consider implementing the preceding FAA and NTSB recommendations.

3.2.2.2 *Expert Panel Recommendations*

The NAV CANADA expert panel agreed, in principle, with the FAA and NTSB recommendations. Regarding "line up and wait" procedures, the expert panel felt that this authorization should not be given, regardless of visibility conditions, when a takeoff delay is anticipated. The expert panel also recommended that direction be given to ATC units to limit and, where practicable, eliminate the use of intersection departures. This latter measure

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[6] ICAO working paper, AN-WP/7542, *"Development of Human Factors-Related Provisions in the PAN-OPS"*, dated 01 June 2000.

[7] NTSB letter A-00-66 through - 71, dated 6 July 2000

has been implemented at Vancouver International Airport to reduce the complexity and potential for error associated with aircraft movements on the departure runway. Vancouver ATC personnel report that this measure has been effective.

3.2.3 Airport Layout(s)

To accommodate higher traffic volume, most major Canadian airports have recently embarked on programs to expand and improve existing infrastructure. In many cases, these improvements have resulted in a more complex aerodrome environment within which pilots and ATS personnel must function. Problems associated with multiple intersecting taxiways and/or runways, particularly those was small angles of divergence, are apparent at many large airports. Such complex intersections are notoriously difficult to sign and, at night, they give rise to the "sea of blue" effect, whereby pilots become confused by the sheer number of taxiway edge lights within their field of view. Navigating accurately in such an environment is a mentally demanding task where the potential for error is frequently realized. The US FAA notes *"Historical data clearly demonstrate that runway incursions most likely to cause accidents generally occur at complex, high volume airports, characterized by parallel/intersecting runways; multiple taxiway/runway intersections; complex taxi patterns; and the need for traffic to cross active runways*[8]*."*

3.2.3.1 Inadequate Standards

In Canada, certified airports are currently governed by TP312, "Aerodrome Standards and Recommended Practices", and specifically by the version of this document that was in effect when the aerodrome was originally certified. Because TP312 has been amended several times, there is effectively no common standard, including those pertaining to aerodrome signs and markings, presently in force at Canadian aerodromes. Although steps are currently being taken to establish a common standard (CAR 322) and despite the fact that many airports *voluntarily* comply with the most recent version of TP312, the adequacy of existing standards for airport signs and markings was frequently challenged during stakeholder consultations. In a recent survey[9] of airline pilots, *"Inadequate and/or confusing airport signs and markings"* was identified as the most important factor contributing to runway incursions. Although pilots frequently complain that existing markings are difficult to see, there is no standard method for measuring the visibility and/or contrast of painted markings to determine their adequacy in various light and environmental conditions. The SCRI believes that a more

[8] 1998 Airport Surface Operations Safety Action Plan to Prevent Runway Incursions and Improve Operations.
[9] AVweb Online Survey, 17 April 2000, www.avweb.com.

objective methodology, supported with the necessary tools and equipment, should be developed to assess the visibility of aerodrome signs and, in particular, painted surface markings.

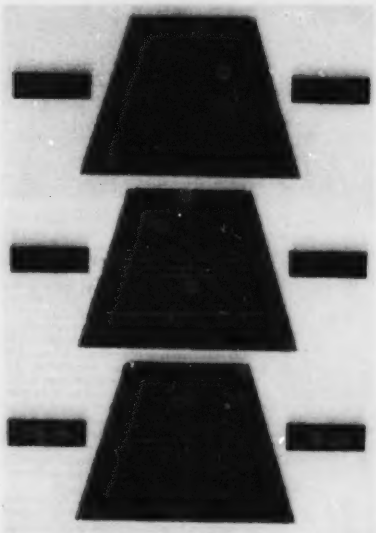
With respect to the growing complexity of taxiway and runway structures, existing versions of TP312 provide limited guidance on practical issues pertaining to airport layout. For example, no guidance is given to limit the number of taxiways or runways that may intersect at approximately the same point. Similarly, no minimum acceptable length is specified for a high-speed runway exit before it intersects another taxiway, runway or parking apron, and common naming conventions for taxiway and/or taxi routes are not provided.

By comparison, the new airport at Oslo, Norway was specifically designed to minimize runway crossing traffic and is equipped with a sophisticated surface movement control system. Similarly, London's Heathrow airport features a traffic lighting system at each runway/taxiway intersection to indicate whether an aircraft should stop or proceed through the intersection. The lights are controlled by two tower technicians. Also at Heathrow, arrivals and departures are performed on separate runways. This latter practice is similar to the arrival and departure procedures at Vancouver International which enjoys the lowest runway incursion rate of any major Canadian aerodrome. The runway incursion rate at Oslo and Heathrow airports are reported to be virtually nonexistent[10].

3.2.3.2 *Selective Lighting Systems to Control Ground Movements*

[10] Air Safety Week, June 19, 2000, Vol. 14, Issue 25.

The viability of using selective lighting to control aircraft ground movements was discussed during stakeholder meetings in Calgary and Toronto. The suggestion was well received, particularly by pilots, who supported the variable message sign implementation advocated by the Air Line Pilot's Association[11] and the switchable stop-bar option that has been proposed by the NTSB. NAV CANADA personnel in Toronto expressed concern over the incremental workload on ground controllers that the operation of a signaling system may induce. There was considerable skepticism that existing ATS staffing levels would permit the effective implementation of additional traffic control measures that must be attended, to any significant degree, by tower personnel. On the other hand, if a requirement is imposed to obtain an explicit clearance to cross every runway (section 3.2.2), ground controller workload and frequency congestion will almost certainly increase. A variable message lighting system would provide a facile method for conveying crossing instructions without adding to frequency congestion.



The issue of selective lighting was also examined by the NAV CANADA expert panel, which identified the same "pros and cons" as previously discussed. After considerable debate, the expert panel concluded that an automatic runway incursion warning system, that requires minimal input from ATS personnel and which provides a direct warning to the pilot, represents a reasonable and cost effective *technical solution* to runway incursions. The installation of electrical induction loops near busy taxiway and runway intersections, can be used to detect approaching aircraft and to trigger lights or other warning mechanisms to compel the pilot to stop the aircraft before a runway incursion occurs. The implementation of this type of warning system can be accomplished at relatively low cost and would capture the spirit of another recent NTSB recommendation: *"The NTSB recommends that the FAA require, at all airports with scheduled passenger service, a ground movement safety system that will prevent runway incursions; the system should provide a direct warning capability to flight crews. In addition, demonstrate through computer simulations or other means that the system will, in fact, prevent incursions. (A-00-66)"*

[11] Air Line Pilot, April 2000, page 26.

3.2.3.3 *Standard Taxi Routes and Improved Access to Airport Diagrams*

The value of defining Standard Taxi Routes (STR) at major airports was discussed at several stakeholder meetings and also by the NAV CANADA expert panel. There was general consensus that STRs, similar to those published in the Canada Flight Supplement (CFS) for Vancouver International Airport, would reduce the potential for frequency congestion at ground control positions and would allow pilots to pre-plan their taxi route before leaving the gate/ramp. In discussing options for promulgating STRs, it was observed that VFR pilots do not normally subscribe to IFR publications and therefore do not have direct access to the detailed airport diagrams contained in IFR publications. The SCRI believes that options should be sought to ensure all pilots have affordable access to airport diagrams and, if applicable, STR descriptions. One option may be to publish diagrams and STR routes for major airports in a format similar to existing Terminal Area Charts. The NAV CANADA expert panel felt that airport diagrams could also serve to indicate to aircrew, through highlighting or colour coding, aerodrome intersections where runway incursions typically occur. Finally, the expert panel observed that existing regulations do not explicitly require that aircrew have an airport diagram available when operating an aircraft on an aerodrome. The SCRI recommends that a regulatory requirement be introduced to require pilots to have an aerodrome map available when operating an aircraft on a *controlled* aerodrome.

3.2.4 Complexity

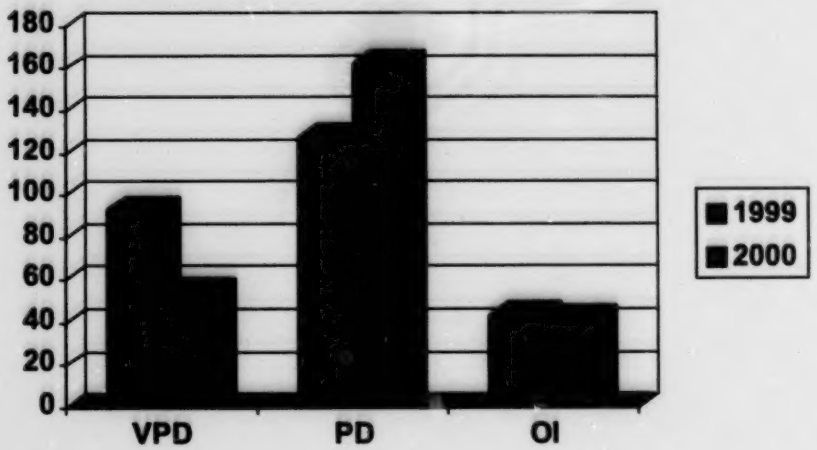
Capacity-enhancing procedures and infrastructure improvements are normally introduced as responses to an increase in traffic volume. Because of this, the effects of increased traffic volume, capacity-enhancing procedures and physical layout may simultaneously exacerbate the runway incursion potential at a particular aerodrome. There is some evidence to suggest that the combined influence of these various factors, the overall *complexity*, is greater than the sum of the constituent parts. Regardless, it is typically against a backdrop of high complexity that a *second-order* effect such as reduced visibility, unfamiliarity or a momentary distraction, becomes the proverbial last straw. Although these effects are clearly important, the SCRI believes that they are most appropriately viewed as the final link in a *causal chain* of events. Second-order effects, such as unfamiliarity, non-standard phraseology or poor visibility, are generally preceded by underlying factors relating to traffic volume, capacity-enhancing procedures and airport layout; all of which contribute to the complexity of the environment within which runway incursions occur. The SCRI believes that effective prevention must focus primarily on tools, procedures and training to more effectively manage the underlying issue of complexity.

3.3 Human Performance Analysis

Whereas traffic volume, capacity-enhancing procedures and aerodrome layout have been shown to increase the *potential* for a runway incursion to occur - *human error* is the mechanism that allows the manifestation of this potential, or probability, in an actual occurrence. Although a general relationship is known to exist between complexity and the propensity for human error, the SCRI sought to gain a more thorough understanding of this relationship by conducting a review of existing sources of occurrence information. Moreover, the SCRI felt obliged to demonstrate through analysis that it is human error, and not some other mechanism, that permits the manifestation of runway incursion potential.

3.3.1 CADORS Database

The CADORS database was originally designed as an event reporting system. Runway incursions are classified as "Pilot Deviation", "Operating Irregularity" typically associated with ATS-related errors, or "Vehicle Pedestrian Deviation" (VPD). Little or no information is recorded in CADORS to support the analysis of "why" a particular event occurred. The scope of information captured by this system is therefore inadequate for a detailed analysis of human errors. Notwithstanding this limitation, CADORS can be used to gain an appreciation of the relative proportion of runway incursions attributable to pilot error, ATS error, vehicle operators and pedestrians. As shown in figure 5, the majority of Canadian runway incursions are associated with pilot errors[12].



[12] Projections for the year 2000 are based on results for the first four months of the year.

Figure 5 - Runway Incursions by Type

According to data published by the FAA, the majority of runway incursions in the United States are also associated with pilot errors. To gain an appreciation of the factors contributing to runway incursions involving pilot deviations, the SCRI examined occurrence reports by the Transportation Safety Board of Canada.

3.3.2 Transportation Safety Board Reports

Searching back to 1997, the SCRI identified a total of 24 Transportation Safety Board (TSB) runway incursion reports. These reports comprised one Class III investigation involving an ATS-related runway incursion and 23 Class V "long reports". Although Class V reports are not investigations, they typically contain a reasonably detailed description of events and circumstances pertinent to the occurrence.

The TSB Class V reports documented 14 runway incursions involving pilot error with the remaining cases involving human errors related to ATS or vehicle operators. Several cases involved unexplained failures by pilots to comply with instructions that had been received and understood. Other cases involved miscommunication between pilots and ATS personnel. In all cases, the runway incursions involved human errors in circumstances that suggest the influence of compiexity and/or workload demand.

3.3.3 NAV CANADA Fact-Finding Boards

The fact-finding board (FFB) is a NAV CANADA process to assess the role played by NAV CANADA employees or facilities in ATS operating irregularities and, if appropriate, to suggest remedial or mitigating action. FFB reports contain detailed information about ATS-related operating irregularities but provide essentially no information about the circumstances associated with pilot errors.

A total of 19 reports from NAV CANADA FFBs were reviewed by the SCRI. All 19 of these reports contained evidence of communication and/or coordination problems in the control tower. The majority of these communication and coordination errors involved the omission of one or more steps in a complex process. In three separate cases, the controller forgot that an aircraft was occupying the runway and cleared another aircraft to land or take off. In three other cases, the controller forgot to issue a hold short clearance and, in another three cases, the airport and ground controllers issued conflicting clearances. In several cases, complex traffic situations, compounded by traffic volume, are assessed to have contributed to memory

lapses or inadequate planning of traffic flow. In one case the controller was trying to cope with 3 active runways and about 20 aircraft simultaneously. One supervisor was covering two tower positions (ground and clearance delivery) and was being distracted from the operational situation by supervisory responsibilities. In yet another case, one controller was on a break and the remaining controller was covering two positions. The TSB attributed one occurrence, in part, to a "sloppy hand-over" which did not sufficiently ensure that the incoming controller had an adequate mental model of the operational situation.

3.3.4 Human Performance Discussion

It is clear that all runway incursions examined by the SCRI were the result of human errors. The adverse influence of high complexity and the attendant workload demand was particularly evident in many of the FFB reports, which contain considerably more detail than CADORS and TSB Class V reports.

Regarding ATS-related errors, it is common to read in FFB and TSB reports that the tower was staffed in accordance with unit policy. However, these same reports clearly indicate that staffing an ATS facility in accordance with unit policy does not guarantee that staffing will be adequate to cope with the workload. This observation supports the SCRI contention that existing tools and procedures for the management of surface traffic at Canadian aerodromes are not adequate to contend with the rapidly growing complexity of aerodrome environments. The issue of complexity should be explicitly considered in devising local traffic procedures and staffing levels.

3.3.5 Limitations of the Data

It is apparent to the SCRI that, with the exception of ATS-related events documented through the FFB process, the collection of runway incursion information is not currently adequate to support a comprehensive analysis of human errors. In order to conduct a human error analysis it is essential that the sequence and circumstances surrounding the occurrence be available so that the unsafe act can be identified unequivocally. Precise identification of the error is a prerequisite for determining the error type. Error type is necessary to guide the search for antecedents or contributing factors. The contributing factors are critical to identification of potential countermeasures.

The level of detail was sufficient to support the analysis in relation to most of the NAV CANADA FFBs, but was most often missing from TSB (Class V) long reports. It was therefore possible to arrive at some general conclusions regarding the contribution of complexity and traffic density to ATC errors,

but the factors contributing to pilot errors are not well defined, even at a general level.

Particularly in view of the preponderance of "pilot deviations" in CADORS runway incursion events, consideration should be given to a more comprehensive data collection and analysis effort relating to pilot errors. The TSB has the capability to collect this data in investigations, but runway incursions are rarely investigated. Transport Canada should consider requesting a TSB Class IV investigation into runway incursions. This would provide an effective avenue to ensure that, for a specified period, the correct data are collected, analyzed and published. Such an investigation may also provide insight into how ATS and pilot actions interact to produce runway incursions[13].

The NAV CANADA expert panel also identified the need to improve the collection and dissemination of information pertaining to runway incursions. The expert panel felt that steps should be taken to consolidate runway incursion data that is separately maintained in the NAV CANADA AOR database and the Transport Canada CADORS database, into a single unified data-store. Aerodrome authorities and commercial operators expressed frustration of the lack of feedback provided to them by Transport Canada about runway incursion occurrences and follow-up actions. They emphasized the requirement to receive from Transport Canada more information about aviation occurrences and follow-up actions as essential inputs to their own safety programs and initiatives.

3.3.6 Training and Awareness

Notwithstanding the lack of detailed information, in both Canada and the United States, about specific factors which may be contributing to runway incursions involving pilot errors, a strong case can be made for promoting runway incursion education and awareness. Simply put, the first step toward finding a solution necessarily involves recognizing and acknowledging that a problem exists. To this end, and in keeping with the FAA recommendation to disseminate information about human performance vulnerabilities leading to runway incursions (paragraph 3.2.2.1), the SCRI recommends that Transport Canada take significant steps to promote runway incursion awareness amongst commercial, corporate and general aviation pilots. This awareness campaign should emphasize the meaning of aerodrome signs and markings, the significance of Land and Hold Short Operations (LAHSO) instructions, taxi procedures, mandatory frequency (MF)

[13] A similar initiative was recently announced by the FAA. *"In April 2000, the FAA established the Runway Incursion Information and Evaluation Program to gather information from pilots involved in runway incursions and determine the causes of the incursions."*

procedures, ICAO standard phraseology for aerodrome surface movements and appropriate error reduction/correction strategies when uncertain of the aircraft position or ATC clearance.

The SCRI notes that deficiencies in the Transport Canada Flight Instructor's Guide were identified by the TSB during the investigation of a runway incursion at Calgary airport on 27 February 1999. The TSB found *that "Little emphasis is placed on learning radio requirements and on the need for heightened situational awareness on a busy airport by the TC Flight Instructor's Guide ..."*[14]. During the NAV CANADA expert panel discussions, concern was expressed that new pilots, particularly those who receive flying training at small, uncontrolled aerodromes, are not always adequately prepared to contend with the complexity of larger aerodromes. SIRO procedures, in particular, are not always covered by flight training schools. The SCRI therefore recommends that steps be taken to ensure that flight training schools are including familiarization and instructions on SIRO for students and renters. As well, the SCRI recommends that the TC flight instructor's guide be amended to place additional emphasis on taxi procedures, SIRO procedures, radio-telephony procedures and correct phraseology. The SCRI also recommends that SIRO and ground movement scenarios be included as a core item in the Transport Canada Pilot Decision Making (PDM) course curriculum.

At stakeholder meetings and again during the expert panel discussions, it was frequently opined that more emphasis should be placed on the investigation and enforcement of aircraft runway incursions. There was general consensus that *visible* enforcement action is an effective tool for promoting increased diligence amongst pilots and ATS personnel. Stakeholders placed particular emphasis on assuring that appropriate enforcement action is seen to occur. Existing mechanisms for disseminating information about enforcement investigations and decisions are perceived by many stakeholders as too limited and generally inadequate. The SCRI therefore recommends that Transport Canada place increased emphasis on the investigation and enforcement of aircraft runway incursions, and on the dissemination of enforcement information to the aviation community.

[14] TSB Report A99W0036, released 14 January 2000.

3.4 Site Analysis

The runway incursion database was sorted to identify airports that have reported 5 or more vehicle or aircraft incursions in 1999 or at least 3 similar incursions (to date) in the year 2000. Fourteen "aerodromes of interest" were identified using this search criteria. The methodology described in section 2.5 was applied to calculate, for each aerodrome, weighted aggregate risk figures for the periods, '97-'00 and '99-'00. Aircraft movement statistics for 1999 were used to calculate, for each aerodrome, a figure representing *"risk per 100,000 aircraft movements"*. Rankings were assigned to the 15 aerodromes using frequency of occurrence, weighted aggregate risk and risk/movement as criteria (Table 3).

Airport	# Reports '97 - '00	Rank	Weighted Risk (R_A) '97 to '00	Rank	Weighted Risk (r_A), '99 & '00	Rank	Risk / Movement (r_{AM})	Rank
CZBB	25	5	75.00	4	72.00	2	33.10	3
CYYC	48	1	148.5	1	100.0	1	37.87	2
CYUL	39	2	101.25	2	58.00	5	26.21	8
CYXD	13	8	66.75	7	63.00	3	68.93	1
CYEG	7	11	26.00	14	20.00	12	18.08	11
CYHM	14	7	37.75	12	28.00	11	28.15	6
CYKF	10	10	41.75	11	38.00	8	27.21	7
CYOW	12	9	43.00	10	30.00	10	16.06	12
CYQB	13	8	44.25	9	33.00	9	23.14	10
CYYZ	28	3	87.00	3	67.00	4	15.77	13
CYTZ	14	7	28.25	13	17.00	13	11.30	14
CYKZ	12	9	53.00	8	49.00	6	29.90	5
CYVR	12	9	24.75	15	14.00	14	3.79	15
CYYJ	21	6	68.25	6	58.00	5	32.23	4
CYWG	32	4	68.50	5	40.00	7	25.55	9

Table 3 - Aerodromes ranked by Weighted Risk and Frequency of Occurrence

The ranking values for Frequency of Occurrence, Weighted Aggregate risk ('99-'00) and Risk/Movement were summed to produce a final rank for each aerodrome. Therefore, the "final rank" value considers the frequency of runway incursions, the severity of these incursions, whether the trend since the beginning of 1999 is increasing or decreasing, and the number of incursions per aircraft movement. A summary of the results is provided in Table 4. Detailed calculations are appended to Annex A of this report.

Airport	# Reports '97 - '00	Rank	Weighted Risk (r_A), '99 & '00	Rank	Risk / Movement (r_{AM})	Rank	Total Score	Final Rank
CZBB	25	5	72.00	2	33.10	3	10	2
CYYC	48	1	100.0	1	37.87	2	4	1
CYUL	39	2	58.00	5	26.21	8	15	4*
CYXD	13	8	63.00	3	68.93	1	12	3
CYEG	7	11	20.00	12	18.08	11	34	10*
CYHM	14	7	28.00	11	28.15	6	24	6
CYKF	10	10	38.00	8	27.21	7	25	7
CYOW	12	9	30.00	10	16.06	12	31	9
CYQB	13	8	33.00	9	23.14	10	27	8
CYYZ	28	3	67.00	4	15.77	13	20	5*
CYTZ	14	7	17.00	13	11.30	14	34	10*
CYKZ	12	9	49.00	6	29.90	5	20	5*
CYVR	12	9	14.00	14	3.79	15	38	11
CYYJ	21	6	58.00	5	32.23	4	15	4*
CYWG	32	4	40.00	7	25.55	9	20	5*

Table 4 - Runway Incursion Ranking

The data in table 3 and table 4 clearly indicate that, by any measure, the runway incursion *"problem"* is more prevalent at some locations than at others. Since 1997, Calgary International Airport (CYYC) has reported consistently high numbers of runway incursions of above average severity. To this day, Calgary is ranked 1st in the country, by a *significant margin*, for runway incursion risk. Since 1999, Boundary Bay airport (CZBB) has reported an alarming number of runway incursions and has remained solidly in 2nd place behind Calgary for more than a year. A concerted local effort to control runway incursions at Boundary Bay, beginning in October 1999, appears to be producing favourable results. Conversely, a sharp increase in runway incursions has been witnessed, during the first half of the current year, at Edmonton City Centre Airport (CYXD).

3.4.1 Calgary International Airport

For the past several years, Calgary International Airport has been the 3rd busiest airport in Canada[15], behind Vancouver International Airport (2nd) and Toronto's Lester B. Pearson International Airport (LBPIA).
It has been opined, in various discussion forums, that the frequency of runway incursions at Calgary International Airport can be attributed in part to the traffic mix at Calgary, comprising approximately 83% IFR and 17% VFR

[15] Based on total aircraft movements published by Statistics Canada

traffic. The proportion of IFR and VFR traffic also reflects the approximate mixture of air carrier traffic and "other" categories of aircraft. It has also been speculated that flight training operations may be adversely influencing the runway incursion rate at Calgary International Airport. However, the SCRI could find no compelling evidence to support these claims. For example, Vancouver International Airport has approximately the same traffic mix as Calgary (78% IFR and 22% VFR) and more total aircraft movements, yet the runway incursion rate at Vancouver International is the lowest of any major Canadian aerodrome. In addition, of the 26 runway incursions reported at Calgary International airport since January 1999, 17 were attributed to pilot deviations, 6 were ATS-related operating irregularities and 3 were vehicle incursions. Eleven of the 17 pilot deviations involved commercial aircraft and the remaining 6 involved General Aviation aircraft. Within the general aviation category, only two runway incursions were associated with training aircraft and/or inexperienced pilots.

A stakeholder meeting was held in Calgary on April 4th to discuss runway incursion issues. There was considerable dialogue about the adequacy of signs and markings at Calgary International Airport. It was observed, for example, that the intersection of taxiway(s) "Charlie-two", "Charlie", "Gulf", and Runway 28 is particularly confusing to pilots and has been the location of several runway incursions. Pilots commented that the signs at this intersection are difficult to see and the narrow angles of divergence between the taxiways make it easy to mistake one taxiway with another. It was also observed that the taxiway naming conventions at Calgary International Airport are not optimized for clear and unambiguous communication of taxi instructions. For example, at the north end of the airport, three taxiways designated, "Charlie", "Charlie-Alpha" and "Charlie-Bravo", converge at a single intersection.

Calgary International Airport was originally designed with a main ramp area at the south end of Runway 34. A new passenger terminal was subsequently constructed at the north end of Runway 34. Movement of aircraft between the north and south terminals is a complicated undertaking and normally involves crossing at least two active runways. Calgary airport routinely operates three active runways, each of which intersects with the main runway (runway 34) and each of which is used for arrivals and departures. SIRO operations and intersection departures are authorized and are commonly employed capacity-enhancing procedures at Calgary International Airport. Since 1997, Calgary has reported 5 runway incursion events involving aircraft that did not, or could not, comply with a "land and hold short" clearance. Four additional runway incursions have resulted from aircraft simultaneously departing, or cleared to depart, from different points on the same runway. It is therefore evident that each of the three main

factors that contribute to runway incursions; high traffic volume, complicated airport layout and capacity-enhancing procedures, are *particularly well represented* at Calgary International Airport. While the finding and implementing of specific solutions is most appropriately left to regional and local authorities, the SCRI believes that preventive actions should focus primarily on reducing or mitigating the complexity of the ground environment at Calgary International Airport.

A temporal analysis of runway incursion events at Calgary International Airport was performed by the SCRI. As shown in Figure 6, the influence of peak periods on the frequency of runway incursions is apparent and may be useful in devising preventive strategies and the promotion of general awareness. Monthly statistics from 1999 (Table 5) confirm that peak traffic at Calgary International typically occurs between 5-7 PM and occasionally between 11-12 AM local time.

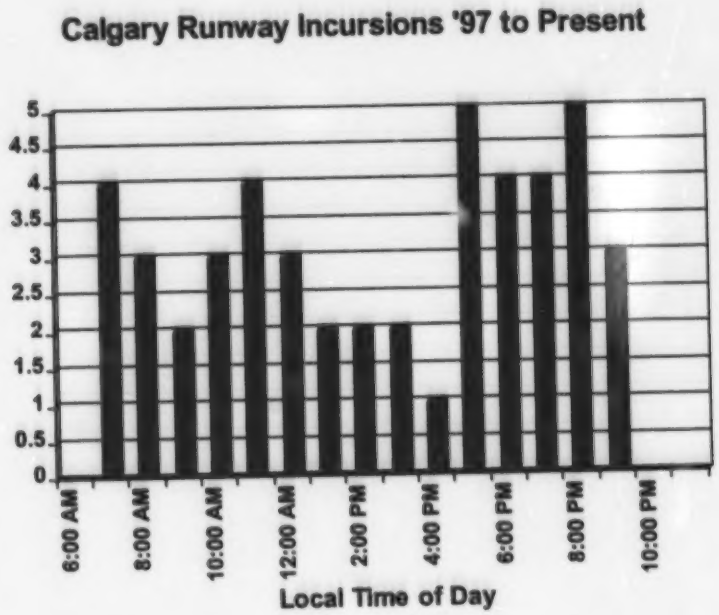


Figure 6 - Temporal Distribution of Runway Incursions - Calgary International

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1700	1200	1700	1800	1100	1900	1100	1800	1800	1700	1700	1700

Table 5 - Peak traffic time at Calgary International Airport, 1999

Canada

3.4.2

Boundary Bay Airport

In 1999, Boundary Bay was the 5th busiest airport in Canada. By virtue of the airport's size and geometry, the intense local training activity and the predominantly VFR traffic mix, Boundary Bay is analogous to Toronto's Buttonville Municipal airport. Also, Boundary Bay and Buttonville are both situated in close proximity to Vancouver International airport and LBPIA respectively. However since 1999, and unlike other similar aerodromes, Boundary Bay has reported an extremely high number of runway incursions. Figure 7 illustrates the temporal distribution of runway incursion events at Boundary Bay airport.

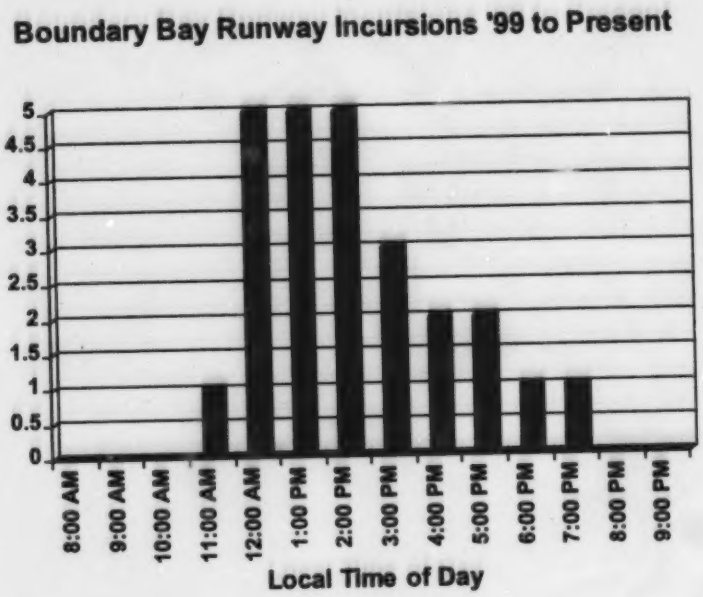


Figure 7 - Temporal Distribution of Runway Incursions - Boundary Bay

An analysis of the 17 runway incursions at Boundary Bay in 1999 revealed that 10 incursions involved aircraft landing on Runway 30 and failing to comply with clearances to hold short of runway 25. Transport Canada's Air Navigation Services and Airspace Directorate assessed eight of these incursions as being directly attributable to the conduct of SIRO operations on runway 25 and runway 30. At the request of the NAV CANADA Site Manager at Boundary Bay airport, a meeting was convened in October 1999 with representatives from the Transportation Safety Board, Transport Canada (Pacific Region) and Boundary Bay Airport. Following this meeting, steps were taken to improve the signs and markings designating the hold lines at

Boundary Bay airport and to clarify the ATC terminology used to communicate hold short restrictions. During the next several months, additional steps were taken to ensure that local and itinerant pilots were familiar with SIRO procedures and hold line designations at Boundary Bay, and aware of runway incursion problem areas (Annex B). Recent occurrence trends suggest that these measures are beginning to have the desired effect. In the first three months of 2000, Boundary Bay reported seven runway incursions, three of which involved aircraft landing on runway 30 and failing to hold short, as cleared, of runway 25. However, during the next three months (April to June 2000), Boundary Bay reported only one runway incursion, involving an aircraft taking off from runway 25 without authorization. These most recent statistics are encouraging and may indicate the successful implementation of preventive measures.

3.4.3 Edmonton City Centre Airport

During 1999, Edmonton City Centre Airport reported 3 runway incursions. However, from January to June 2000, this airport reported 9 runway incursions, more than any other aerodrome in Canada. During the same period, average traffic volume increased by approximately 7%, compared to traffic statistics for the same period in 1999. Whereas the runway incursion rate at Boundary Bay Airport appears to be abating, precisely the opposite is true for Edmonton City Centre Airport.

A detailed analysis of runway incursion issues at specific airports was beyond the scope of the SCRI mandate and, in any case, is best left to local and regional experts. However, on the basis of clear and persistent statistical evidence of abnormally high risk, the SCRI feels strongly that an *in-depth study* of runway incursion risks at Calgary International Airport is warranted. Although emerging trends at Boundary Bay Airport and Edmonton City Centre Airport are more recent and arguably less compelling, events at both sites should be closely monitored. As a first priority, a runway incursion action plan for Edmonton City Centre Airport should be developed and implemented by local authorities.

3.5 Process Analysis

3.5.1 Reactive Mechanisms

At aerodromes where NAV CANADA maintains a presence, procedures exist to facilitate the timely and accurate reporting of runway incursion events. In virtually all cases, runway incursion events are reported by NAV CANADA to

Transport Canada. The civil aviation "system" typically invokes one, or more, of the following responses to a runway incursion report:

a) NAV CANADA FFB - normally convened when an ATS operating irregularity is believed to have contributed to the runway incursion event;
b) TSB investigation or Class V report - normally reserved for runway incursions that are sufficiently serious to become "reportable occurrences" as defined by the CTAISB Act;
c) Internal action at Transport Canada, including enforcement; and
d) Action by aerodrome authorities - particularly in response to vehicle and pedestrian incursions.

None of these processes offer a comprehensive approach to identifying risk, implementing and *communicating* prevention strategies and monitoring the effect of these strategies. For example, runway incursions are rarely the subject of a TSB investigation and FFBs are not public documents. Therefore, detailed analyses of runway incursion events and related hazards, or safety deficiencies, are seldom available. When safety deficiencies are identified, preventive measures may be implemented by one or more agencies within Transport Canada, by NAV CANADA, by an aerodrome authority or by a commercial aircraft operator - all of whom maintain largely independent systems for recording the nature of the preventive measures taken, the rationale for implementing these measures and whether or not these measures had the desired result. Finally, and contrary to a fundamental principle of safety management, no standard protocol exists to assure that the reporting agency is apprised of what, if any, preventive action is taken in response to an occurrence report. Regarding safety issues, and specifically with respect to runway incursions, there was consensus that the communication and coordination of safety information and actions between Transport Canada, NAV CANADA and Aerodrome Authorities should be improved. The SCRI supports the expert panel recommendation that NAV CANADA and Transport Canada establish a **shared data store** to record detailed information about runway incursion events, follow-up reports, and preventive actions subsequently taken. As well, the SCRI recommends that a process be established to ensure that this information is shared with aerodrome authorities and aircraft operators.

3.5.2 Proactive Mechanisms

Aerodromes, Air Traffic Service (ATS) providers and aircraft operators are the three main components of the Civil Aviation System. Whereas, Canadian Aviation Regulations require that safety programs be maintained by ATS providers and commercial air operators, there is currently no regulatory requirement for airport authorities to implement a "safety management

system" or similar performance based mechanism, through which Transport Canada may reasonably expect to remain cognizant of *airport safety issues*. Airport safety committees currently exist at many airports and are an excellent tool for proactively focusing local resources on high-risk safety deficiencies. These same committees, given appropriate reporting guidelines, could be used by Transport Canada to oversee the management of airport safety issues and, where necessary, to proactively intervene in the finding and implementation of effective preventive measures. The SCRI recommends that Transport Canada review existing regulatory requirements for ATS service providers, Certified Airports and Commercial Aircraft Operators, to ensure that the principles of safety management and oversight are applied consistently to all components of the aviation system.

In a more general sense, and notwithstanding recent efforts to embrace the principles of safety management, a standard process has not been established for assessing and describing the risk associated with known safety deficiencies. The introduction of a such a risk assessment framework would establish a common language, or nomenclature, that could be used by all stakeholders in the aviation "system" to measure and describe risk, and to guide subsequent decisions pertaining to preventive or remedial actions. The SCRI recommends that Transport Canada define and promulgate a process for assessing and describing the safety risk associated with potentially hazardous conditions and procedures. It is believed that a common risk assessment process will facilitate the unambiguous communication of safety information between the various stakeholders in the aviation system.

4. Recommendations

The SCRI recommends that:

4.1. In consultation with NAV CANADA, Transport Canada formalize and promulgate the following runway incursion definition: *"Any occurrence at an aerodrome involving the unauthorized or unplanned presence of an aircraft, vehicle or person on the protected area of a surface designated for aircraft landings or departures."*

4.2. Transport Canada develop and administer a comprehensive and *recurring* runway incursion awareness program, possibly in collaboration with NAV CANADA, the Canadian Airports Council and other professional aviation organizations.

4.3. Transport Canada focus on developing preventive strategies for runway incursions that result from *pilot deviations*. Immediate action should be taken to disseminate, on a recurring basis, information to pilots about human performance vulnerability to error due to workload, and potential distractions associated with the performance of cockpit tasks.

4.4. Transport Canada training guidelines and audit processes be revised to place additional emphasis on radio-telephony procedures and ICAO standard phraseology, familiarity with SIRO operations, pre-planning and briefing of intended taxi routes prior to arrival and departure, and minimizing other cockpit tasks while taxiing. The Transport Canada Flight Instructor's Guide should be amended to reflect these principles.

4.5. Transport Canada require that an explicit ATC clearance be given for an aircraft to cross any runway.

4.6. Transport Canada ensure that existing "line up and wait" procedures are revised to preclude aircraft from being positioned on an active runway if a take-off delay is anticipated.

4.7. Transport Canada work in collaboration with ATS service providers to develop a policy regarding runway intersection departures. The intent of this policy should be to minimize or, when practicable, eliminate the use of intersection departures.

4.8. Transport Canada establish guidelines for the promulgation of standard taxi routes and encourage the implementation of standard taxi routes, where practicable, at controlled airports.

4.9. Transport Canada develop and implement **common** standards and recommended practices (CAR 322) for all Canadian aerodromes.

4.10. Transport Canada place more emphasis, particularly during airport inspections, on ensuring that airport signs and markings are clearly visible to aircraft on the manoeuvring surface and are unambiguous.

4.11. In consultation with airport authorities, Transport Canada investigate the viability of an automated runway incursion warning system, using inductive loop or similar technology, that provides a direct warning of an approaching hold line to the pilot.

4.12. Transport Canada establish standards pertaining to the number of runways and/or taxiways that can intersect at approximately the same point and for the minimum angle of divergence of intersecting taxiways and runways.

4.13. Transport Canada promulgate ICAO standard naming conventions for taxiways and, if applicable, standard taxi routes.

4.14. Transport Canada investigate the feasibility of developing an objective methodology, and associated equipment, to determine when airport surface markings need repainting due to rubber obscuration, normal wear, fading, lack of contrast with the pavement, or other reasons.

4.15. Transport Canada investigate the feasibility of making aerodrome maps available to pilots at reduced cost, possibly by making them available on the INTERNET or by producing these maps in a format similar to terminal area charts.

4.16. Transport Canada extend the intent of CAR 705.07(2), Air Operator Flight Safety Program and CAR 573.09 (NPA 2000-031), Quality Assurance Program, to include certified airports, possibly by amending CAR 302.07.

4.17. Transport Canada initiate a program, possibly in cooperation with NAV CANADA, to better understand the human factors that are contributing to runway incursions and, in particular, to examine the influence of increasingly complex procedures and layouts on the performance of pilots and ATS personnel engaged in ground operations. The value of requesting a TSB Class 4 investigation, as a means of collecting detailed occurrence information, should be considered.

4.18. Transport Canada and NAV CANADA establish a shared database to record runway incursion occurrences, investigation, analysis and follow-up actions.

4.19. Transport Canada provide regular updates to airport authorities, commercial operators and other stakeholders on runway incursion statistics and ongoing preventive measures.

4.20. Transport Canada place increased emphasis on the investigation and enforcement of aircraft runway incursions and, in particular, on communicating enforcement decisions to the aviation community.

4.21. Transport Canada adopt a *risk-based, data-driven* approach to monitor runway incursion occurrences, on an *ongoing basis*, to measure the efficacy of newly implemented preventive strategies and to proactively target preventive actions at specific airports where the risk associated with runway incursions is particularly high.

4.22. Transport Canada, working in partnership with NAV CANADA, the airport authority and local stakeholders, conduct an in-depth study of the runway incursion risk at Calgary International Airport and assess the adequacy of existing and future preventive measures.

4.23. Transport Canada monitor and, if necessary, facilitate the development and implementation of runway incursion preventive measures at Edmonton City Centre Airport.

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 &'00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						174109				
1997	0	0	0	0	0	208139	0			
1998	0	0	0	1	1	212572	4			
1999	0	1	15	1	17	217455	34			
2000	0	0	6	1	7		19			

Table A1 – Boundary Bay Airport – CZBB

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A) '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						235184				
1997	0	4	7	3	13	238958	43			
1998	0	2	7	2	11	257836	36			
1999	0	2	8	6	16	264085	50			
2000	0	0	7	0	7		25			

Table A2 – Calgary International Airport – CYYC

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						202221				
1997	0	6	1	3	10	195043	25			
1998	0	8	3	4	15	209173	41			
1999	1	5	1	0	7	221282	14			
2000	0	3	3	1	7		22			

Table A3 – Dorval Airport – CYUL

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						84453				
1997	0	0	0	0	0	78816	0			
1998	0	0	2	0	2	84488	5			
1999	0	0	2	1	3	91397	11			
2000	0	2	3	3	8		26			

Table A4 – Edmonton City Centre Airport – CYXD

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 &'00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						174109				
1997	0	0	0	0	0	208139	0	75		
1998	0	0	0	1	1	212572	4			
1999	0	1	15	1	17	217455	34		72	33.1
2000	0	0	6	1	7		19			

Table A1 – Boundary Bay Airport – CZBB

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A) '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						235184				
1997	0	4	7	3	13	238958	43	148.5		
1998	0	2	7	2	11	257836	36			
1999	0	2	8	6	16	264085	50		100.0	37.87
2000	0	0	7	0	7		25			

Table A2 – Calgary International Airport – CYYC

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						202221				
1997	0	6	1	3	10	195043	25	101.25		
1998	0	8	3	4	15	209173	41			
1999	1	5	1	0	7	221282	14		58	26.21
2000	0	3	3	1	7		22			

Table A3 – Dorval Airport – CYUL

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						84453				
1997	0	0	0	0	0	78816	0	66.75		
1998	0	0	2	0	2	84488	5			
1999	0	0	2	1	3	91397	11		63.0	68.93
2000	0	2	3	3	8		26			

Table A4 – Edmonton City Centre Airport – CYXD

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						90805				
1997	0	0	0	0	0	107378	0	26.0		
1998	0	0	0	2	2	114692	8			
1999	0	0	2	2	4	110590	14		20.0	18.08
2000	0	0	0	1	1		3			

Table A5 – Edmonton International Airport – CYEG

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						85994				
1997	1	0	2	0	3	94085	6	47.75		
1998	0	1	3	0	4	94276	9			
1999	1	1	5	0	7	99457	16		28.0	28.15
2000	0	0	3	0	3		6			

Table A6 – Hamilton Airport – CYHM

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						80340				
1997	0	0	0	0	0	103653	0	41.75		
1998	0	1	1	0	2	132377	5			
1999	0	0	4	1	5	139647	18		38.0	27.21
2000	0	0	3	0	3		10			

Table A7 – Kitchener/Waterloo Regional Airport – CYKF

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						163698				
1997	0	0	0	1	1	169290	5	43.0		
1998	0	0	4	1	5	181861	14			
1999	0	0	4	1	5	186770	18		30.0	16.06
2000	0	0	1	1	2		6			

Table A8 – Ottawa International Airport – CYOW

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						90805				
1997	0	0	0	0	0	107378	0			
1998	0	0	0	2	2	114692	8			
1999	0	0	2	2	4	110590	14			
2000	0	0	0	1	1		3			

Table A5 – Edmonton International Airport – CYEG

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						85994				
1997	1	0	2	0	3	94085	6			
1998	0	1	3	0	4	94276	9			
1999	1	1	5	0	7	99457	16			
2000	0	0	3	0	3		6			

Table A6 – Hamilton Airport – CYHM

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						80340				
1997	0	0	0	0	0	103653	0			
1998	0	1	1	0	2	132377	5			
1999	0	0	4	1	5	139647	18			
2000	0	0	3	0	3		10			

Table A7 – Kitchener/Waterloo Regional Airport – CYKF

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						163698				
1997	0	0	0	1	1	169290	5			
1998	0	0	4	1	5	181861	14			
1999	0	0	4	1	5	186770	18			
2000	0	0	1	1	2		6			

Table A8 – Ottawa International Airport – CYOW

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						132575				
1997	0	0	1	1	2	125291	6			
1998	0	1	1	1	3	131550	11			
1999	1	4	0	0	5	142631	13			
2000	0	1	1	1	3		10			

Table A9 – Quebec International Airport – CYQB

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						372419				
1997	0	0	4	5	9	395637	7			
1998	0	1	3	3	7	421028	22			
1999	0	0	0	5	5	424846	17			
2000	0	0	6	1	7		25			

Table A10 – Toronto International Airport – CYYZ

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						124670				
1997	0	0	0	0	0	126138	0			
1998	3	2	2	1	8	148248	15			
1999	1	0	4	1	6	150454	17			
2000	0	0	0	0	0		0			

Table A11 – Toronto City Centre Airport – CYTZ

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						149,584				
1997	0	1	0	1	2	161,210	8			
1998	2	0	0	0	2	170,246	0			
1999	0	0	4	0	4	163,900	13			
2000	0	0	4	0	4		16			

Table A12 – Toronto Buttonville Municipal Airport – CYKZ

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						132575				
1997	0	0	1	1	2	125291	6	44.25		
1998	0	1	1	1	3	131550	11			
1999	1	4	0	0	5	142631	13		33.0	23.14
2000	0	1	1	1	3		10			

Table A9 – Quebec International Airport – CYQB

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						372419				
1997	0	0	4	5	9	395637	7	87.0		
1998	0	1	3	3	7	421028	22			
1999	0	0	0	5	5	424846	17		67.0	15.77
2000	0	0	6	1	7		25			

Table A10 – Toronto International Airport – CYYZ

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						124670				
1997	0	0	0	0	0	126138	0	28.25		
1998	3	2	2	1	8	148248	15			
1999	1	0	4	1	6	150454	17		17.0	11.30
2000	0	0	0	0	0		0			

Table A11 – Toronto City Centre Airport – CYTZ

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						149,584				
1997	0	1	0	1	2	161,210	8	53.0		
1998	2	0	0	0	2	170,246	0			
1999	0	0	4	0	4	163,900	13		49.0	29.90
2000	0	0	4	0	4		16			

Table A12 – Toronto Buttonville Municipal Airport – CYKZ

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						329961				
1997	0	2	1	1	4	342552	14	24.75		
1998	0	0	2	0	2	368675	5			
1999	0	1	3	1	5	369126	6		14.0	3.79
2000	0	0	1	0	1		4			

Table A13 – Vancouver International Airport – CYVR

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						159792				
1997	0	0	5	0	5	174513	16	68.25		
1998	0	0	1	0	1	183180	3			
1999	1	3	8	1	13	179969	42		58.0	32.23
2000	0	0	1	1	2		8			

Table A14 – Victoria International Airport – CYYJ

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A),'97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						155084				
1997	2	2	2	1	7	155221	18	68.5		
1998	0	2	4	3	9	150271	26			
1999	0	1	10	3	14	156527	36		40.0	25.55
2000	1	0	1	0	2		2			

Table A15 – Winnipeg International Airport – CYWG

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						329961				
1997	0	2	1	1	4	342552	14			
1998	0	0	2	0	2	368675	5			
1999	0	1	3	1	5	369126	6			
2000	0	0	1	0	1		4			

Table A13 – Vancouver International Airport – CYVR

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A) '97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						159792				
1997	0	0	5	0	5	174513	16			
1998	0	0	1	0	1	183180	3			
1999	1	3	8	1	13	179969	42			
2000	0	0	1	1	2		8			

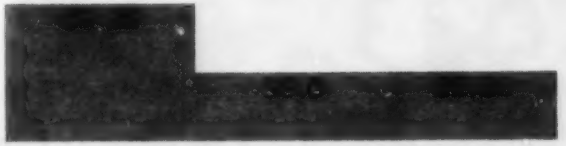


Table A14 – Victoria International Airport – CYYJ

Annex A – Weighted Aggregate Risk Tables

Year	Runway Incursions					Annual Aircraft Movements	Aggregate Risk	Weighted Risk (R_A),'97 to '00	Weighted Risk (r_A), '99 & '00	Risk / Movements
	Ped	Veh	PD	OI	Total					
1996						155084				
1997	2	2	2	1	7	155221	18			
1998	0	2	4	3	9	150271	26			
1999	0	1	10	3	14	156527	36			
2000	1	0	1	0	2		2			

Table A15 – Winnipeg International Airport – CYWG

Annex B – Boundary Bay Action Planning

BY FAX:

TAMB 5151-P562(TA)

Boundary Bay Airport Corporation
R.R. #1
Delta, B.C.
V4K 3N2

Attention: Ran Vered, Airport Manager

Dear Sir:

RE: Simultaneous Intersecting Runway Operations (SIRO)

The following is the decision record of our meeting held October 12th, 1999 at Boundary Bay Control Tower.

The purpose of the meeting was to;

- review the recurring incidences of aircraft operators disregarding Air Traffic Control instructions to hold short during SIRO,
- review the existing procedures and infrastructure pertain to SIRO, and
- present solutions to improve SIRO at Boundary Bay Airport.

Attendees:

- Rob Ogden; Aerodrome Safety, Transport Canada Chair:
- Linda Todd; Acting Tower Manager, Boundary Bay Tower; NAV CANADA.
- Lana Graham; Regional Safety Manager, NAV CANADA.
- Ran Vered; Airport Manager, Boundary Bay Airport.
- Damien Lawson; Transportation Safety Board.
- Toke Adams; Aerodrome Safety, Transport Canada.

.../2

Decisions and actions discussed and agreed to for implementation were:

1. PRIORITY: relocate the existing Mandatory Instruction signs to nine meters from runway edge. **Action by: Airport Manager**

2. Outline the hold lines in black to increase their conspicuity. **Action by: Airport Manager**

3. Change the Mandatory Instruction signs to read "07 - 25" not just "07" **Action by: Airport Manager**

4. Relocate the existing information sign "A" so it is not collocated with Mandatory Instruction sign. **Action by: Airport Manager**

5. Repaint the borders of all Mandatory Instruction Signs in black rather than white. **Action by: Airport Manager**

6. A meeting is to be arranged with the Flight Schools and other tenants to advise them of the occurrences during SIRO and ensure that instructors and students understand SIRO procedures. **Action by: Airport Manager & NAV CANADA.**

7. The next edition of the Boundary Bay Airport Newsletter will be published reasonably soon and will have a feature on SIRO. **Action by: Airport Manager and NAV CANADA.**

8. An advisory pamphlet/poster on SIRO will be produced and displayed in all flight planning rooms and other visible public locations for review by local and itinerant pilots. **Action by: Airport Manager**

9. Amend ATC Phraseology; change *"Hold short runway 25"* to *"Hold short runway 07-25"* and when aircraft are cleared beyond their landing hold short point add *" hold short canceled, continue across 07-25 to taxiway A".*

Action by: NAV CANADA

10. Request for Transport Canada, Enforcement to follow up on incursion incidences. **Action by: Transport Canada, Aerodrome Safety**

11. Request for Transport Canada, Flight Training Standards to ensure flight training schools are including familiarization and instructions on SIRO for students and renters. **Action by: Transport Canada, Aerodrome Safety**

12. Request for Transport Canada, System Safety to include SIRO familiarization at next scheduled Pilot Decision Making Program conducted at the Boundary Bay Airport. **Action by: Transport Canada, Aerodrome Safety.**

13. Request for Transport Canada, System Safety to assist the APM in the production of a safety pamphlet/poster on SIRO and/or make this a subject for a "take five" notice. **Action by: Transport Canada, Aerodrome Safety.**

14. A night evaluation of SIRO once signage has been relocated. **Action by: Transport Canada, Aerodrome Safety**

15. A review to be coordinated for May 2000 to ensure all changes initiated have been successful. **Action by: Transport Canada, Aerodrome Safety**

If you have any questions or need further information, please contact me, at (604) 666-3527.

Yours truly,

Toke Adams
Civil Aviation Safety Inspector
Aerodrome Safety

cc. Linda Todd, NAV CANADA
Lana Graham, NAV CANADA
Damien Lawson, TSB
Rob Ogden, Transport Canada; TAMB

April 14, 2000

To: All Tenants and Users of Boundary Bay Airport

RE: Runway incursions

As a result of frequent runway incursions at Boundary Bay Airport, Transport Canada Aerodrome Safety (TC) has suggested a few ideas in order to eliminate the problem. One of the suggestions was to put highly visible markers adjacent to every hold short line. In the near future Boundary Bay Airport Corporation (BBAC) will install highly visible, retro-reflective, one foot tall pylons. You will notice three pylons extending from each side of the hold short lines.

The existing hold short lines retain their status as the designated holding positions of the pylons. These pylons are unique to Boundary Bay Airport, so do not expect to see them at other Canadian airports.

Other measures to deal with the above-mentioned problem are to be undertaken in the future. We encourage all the tenants and users to give us feedback on our improvements.

We request that all users be aware of the runway incursion problem at Boundary Bay Aiport and take every measure to avoid further incidents.

Thank you.
Ran Vered
Boundary Bay Airport Manager

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